DOCUMENT RESUME

ED 381 396 SE 056 254

AUTHOR Lin, Sheau-Wen; Yang, Jong-Hsiang
TITLE Biology Teachers' Knowledge Base of Instructional Representations.
PUB DATE Apr 95
NOTE 23p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (San Francisco, CA, April 22-25, 1995).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Biology; Foreign Countries; Junior High Schools; *Knowledge Base for Teaching; Science Instruction; Science Teachers; Secondary School Teachers; *Teacher Education
IDENTIFIERS *Instructional Representations; Taiwan

ABSTRACT

Based on the assumption that much can be learned from the studies of experienced science teachers, the purpose of this study is to identify the knowledge base that contributed to the instructional representations demonstrated by four exemplary junior high school biology teachers. Results are intended to provide suggestions that would be useful to science teacher educators and science teachers. Multiple qualitative data gathering methods and triangulation were employed to enhance the validity of the findings. Analysis indicated that the knowledge base of the teachers' instructional representations consisted of five major categories: knowledge of subject matter, students, curriculum, context, and alternative representations. Each category had several chief subcategories. These categories overlapped and interacted with each other. The results indicate that it is important to provide science teachers with knowledge in the five major categories and that it is necessary to help teachers integrate the different categories of knowledge for teaching. Contains 26 references. (LZ)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 381 396

BIOLOGY TEACHERS' KNOWLEDGE BASE OF INSTRUCTIONAL REPRESENTATIONS

Sheau-Wen Lin and Jong-Hsiang Yang
National Taiwan Normal University

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
SHEAU-WEN LIN
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it
Minor changes have been made to improve reproduction quality
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

Paper Presented at the Annual Meeting of National Association for Research in Science Teaching

San Francisco CA. April 22-25, 1995

SE 055 254

BIOLOGY TEACHERS' KNOWLEDGE BASE OF INSTRUCTIONAL REPRESENTATIONS

Sheau-Wen Lin and Jong-Hsiang Yang, National Taiwan Normal University

The purpose of this study was to identify the knowledge base that contributed to the biology teachers' instructional representations. Participant observation, interview and various related documents were used to collect data from four exemplary junior high school biology teachers. Analysis indicated that the knowledge base of their instructional representations consisted of five major categories: knowledge of subject matter, students, curriculum, context, and alternative representations. Each category had several chief subcategories. These categories overlapped and interacted with each other. The knowledge base of their instructional representations made them teach effectively.

BIOLOGY TEACHERS' KNOWLEDGE BASE OF INSTRUCTIONAL REPRESENTATIONS

INTRODUCTION

For many teachers, teaching is merely a simple transmission of subject matter to their students. They prepare their lessons by reviewing or learning the subject matter that will be transmitted. Students are asked to memorize the content. It leaves little space for teachers to think in a pedagogically oriented way. However as teaching is concerned with learning, it requires thinking about how to build bridges between teachers' understanding and that of their students. The transformation of subject matter into forms that are comprehensible to students is the central intellectual task of teaching(Shulman, 1986; 1987).

From the view of representation to exam instruction, several characteristics of teaching are illuminated. First, instructional representations put emphasis on the wholeness of teaching content and strategies. Teaching strategies may teach planned and implicit information. Content and strategies both influence student learning(McDiarmid, Ball & Anderson, 1989). Second, instructional representations explicate the subject-specific properties of teaching(Shulman, 1986). Teachers need to consider the different issues in different subject matter when they transform subject matter and select and evaluate representations. These activities are not content-free(McDiarmid, Ball & Anderson, 1989). Third, the interactive nature of various types of representations makes it essential for teachers consider the difference in students to make subject matter meaningful to students(Post & Cramer, 1989). Finally, the incompleteness of representations enables teachers to be aware of the limitations of different representations. Every representation has its own advantage and limitations. When facilitating student learning, they may simultaneously mislead their understanding(Bruner, 1966; Geddis et al. 1993).

Studies have shown that teachers' knowledge influences their instructional actions and ultimately impacts on the learning that takes place in school(e.g., Clark & Peterson, 1986). For presenting effective representations, what kinds of knowledge do teachers need? Based on the assumption that much can be learned

from the studies of experienced science teachers, the purpose of this study was to identify the knowledge base that contributed to the instructional representations demonstrated by four exemplary biology teachers. The results were intended to provide suggestions that would be useful to science teacher educators and science teachers.

LITERATURE REVIEW

Studies of teacher knowledge have shown that experienced teachers develop a knowledge base over time. Peterson and Comeaux(1987)described teachers' knowledge as the mental scaffolding. Leinhardt and Greeno(1986)described teaching as a complex cognitive skill in which teachers built up a knowledge base of complex schemata for teaching. Experienced teachers had better developed schemata than novice teachers. In the study by Carter(1990), it was demonstrated that expert teachers have a sense of "the collective wisdom of the profession". Berliner(1987)suggested that teachers developed complex cognitive schemata through planning, interactive teaching, and reflecting. As they gained more expertise, they became more able to draw upon their knowledge and experience.

Sanders et al. (1993)examined the influence of teachers' content knowledge, pedagogical knowledge, and pedagogical content knowledge on their planning, teaching, and reflecting when teaching in and out of science specialty areas. Their wealth of pedagogical knowledge and pedagogical content knowledge for general science topics seemed to sustain teachers in each area. Limitations in content knowledge and pedagogical content knowledge about specific science content were particularly evident in the teachers' interactive teaching outside their science specialty areas.

Some studies in science education focused especially on the role of content knowledge. They suggest that teachers' knowledge of content do influence teaching activities. The study by Gess-Newsome and Lederman(1995)described that level of content knowledge had a significant impact on how content was taught. Teachers made a greater number of integrative connections among content topics that were part of their specialities than those out of this area. Weak content knowledge affected teachers taught content in different ways. For instance, one teacher taught the

topics in a superficial manner, another one dropped the unit from the curriculum.

Carlsen(1991)examined the relationship of new biology teachers' subject matter knowledge to their planning. The result showed that when the content was familiar, teachers were more likely to use whole class instruction, and.when the content was unfamiliar they were more likely to use student-centered activities.

Hashweh(1987) compared the teaching of experienced biology and physics teachers when they taught both biology and physics. The result indicated that teachers' subject matter knowledge influenced planning, response to students' questions, and lesson structure.

Subject matter knowledge includes not only an understanding of facts and concepts of a discipline, but also an understanding of the methods and rules that guide study in the discipline(Shulman, 1986). Schwab (1978)described the structure of a discipline in terms of substantive and syntactical knowledge.

It is necessary for science teachers to have the subject matter knowledge, but it is not sufficient for generating instructional representations. Teachers need to consider other factors to communicate knowledge to students. To accomplish these transformations, teachers draw on diverse kinds of pedagogical content knowledge. Pedagogical content knowledge is "a blend of pedagogy and content which includes an understanding of how the topics of instruction are organized, represented, and adapted to students, and presented in the classroom context"(Shulman, 1987). Pedagogical content knowledge also includes the ways of representing and formulating the subject that make it comprehensible to students and an understanding of what makes the learning of specific topics easy or difficult(Shulman, 1986). This knowledge develops in a cyclic process in which teachers comprehend, transfer, instruct, evaluate, reflect, gain new comprehension, and transfer again(Shulman, 1987).

Marks(1990)presented a description of pedagogical content knowledge in mathematics. He suggested modifications in a conception of pedagogical content knowledge consisting of four components: subject matter for instructional purposes, students' understanding of the subject matter, media for instruction in the subject matter, and instructional processes for the subject matter.

Grossman(1989) developed a framework of pedagogical content knowledge to examine the influence of teacher education on teachers' knowledge growth. The definition of pedagogical content knowledge was based on four components: knowledge of students' understanding, curriculum, instructional strategies, and purposes for teaching.

Based on a constructivist view, Cochran et al. (1993)proposed the definition of pedagogical content knowing as following: "a teacher's integrated understanding of four components of pedagogy, subject matter, students characteristics, and the environmental contexts of learning." They placed more emphasis than Shulman on the necessity of understanding of students and the social, political, cultural and physical environmental contexts in teachers' pedagogical content knowing.

Geddis et al. (1993)described two student teachers' attempt at teaching chemical isotopes. In the course of analysis, examples of four distinct categories of pedagogical content knowledge were articulated. Knowledge of learners' prior knowledge, effective teaching strategies, alternative representations, and curricular saliency are all important components of pedagogical content knowledge.

These studies(Cochran et al. 1993; Geddis et al. 1993; Grossman, 1989; Marks, 1990; Shulman, 1987)explored components of pedagogical content knowledge and they suggested that pedagogical content knowledge played an important role in the transformation of subject matter. Most of these researchers tried to articulate the concept of pedagogical content knowledge by exploring the knowledge growth in students teachers.

Based on the "The Search for Excellence" and similar studies that have caused considerable excitement and motivation among teachers, this study explores the knowledge base of representations in exemplary teachers. The assumption is that much can be learned from the studies of expert science teachers. Also, such case studies of exemplary practices lead improvements in science teaching by motivating and guiding science teachers' attempts to improve their practices.

METHODS

Interpretive methods described by Erickson(1986) were used in this study. Multiple qualitative data gathering methods and

triangulation were employed to enhance the validity of the findings.

Selection of teachers

The exemplary teachers for this study were selected from the list of candidates of exemplary biology teachers as nominated by the science education experts and scholars. An observation of potential participants' classroom teaching was also conducted to select candidates who demonstrated expert teaching characteristics. The "Criteria of Excellence: Biology Teachers of Junior High School" embodied the expert characteristics of biology teaching as an accredited subject. The criteria, including teaching style, professional skills, teaching environment, community involvement, and professional development, were set up by previous studies(News and Views, 1989; Penick, 1984; Yager, 1986). Then, the exemplary teachers and the school administrators were approached for cooperation. Through this procedure four exemplary teachers were selected.

Context and participants

Four female teachers, Amy, Betty, Christine, and Debra had taught biology in junior high school for 26, 13, 13, and 18 years respectively. Both Amy's and Betty's schools located in Taipei city, Christine's in Taipei county, and Debra's in Keelung city. One of the teacher's classes was observed. There were about 38 to 48 students in the participating classes.

The teachers had professional training in biology. Amy had received her bachelor degree of health education. Betty, Christine, and Debra had achieved their bachelor degree of biology. They had all earned some master level credits in biology.

All four teachers had won outstanding awards. Amy had won "Awards for Outstanding Achievement in Taipei Municipal Science Fair". Betty had won "Awards for Outstanding Achievement in Taipei Municipal Science Fair", "Awards for Outstanding Achievement in Taipei Municipal Teaching Aids Presentation", and "Annual Outstanding Teachers' Award". Christine and Debra had won "Awards for Outstanding Achievement in Taiwan Provincial Science Fair". Debra also had won "Award of Taiwan Provincial Test Designing Fair".

Data collection

Data was collected mainly by means of participant observations, interviews, and documents reviewed. Participant observations were performed for at least 28 lessons in a duration of 10-12 weeks. The teachers were interviewed before or after each classroom observation with respect to their instructional representations. All observations and interviews were video or tape recorded. Related documents including teaching aids, outlines, record sheets, and tests were preserved with photocopies or photography.

A random sampling technique was used to select six students from above-average, average, and below-average achievement groups in each participating class. They were interviewed by the researchers at the end of the observations. The interviews with each student took about 50 min. These students provided information on their perceptions of the manner in which biology teaching and learning occurred during the study.

Data analysis

The data base consisted of field notes and transcriptions from observations, interviews, and documents. Vignettes were taken from field notes and transcriptions to describe the teaching practice and tentative assertions of the practice. These vignettes were discussed with the teachers, regularly throughout the study, to confirm the meaning of their behaviour. Four teachers were also asked to comment on any ideas that they believed to be misrepresented or incomplete. Then, all the vignettes were coded and classified. Major categories were alternative instructional representations, knowledge of subject matter, knowledge of curriculum and teaching media, knowledge of students, and knowledge of teaching context. Within each category were many subcategories, such as forms of instructional representations, models of using representations, and contexts of using representations in the category of alternative representations. All the vignettes were examined for trends and frequency. At this time tentative hypotheses about the knowledge base of content representations were formed. Then the specific trends were explored and more concrete hypotheses were formulated and tested by subsequent coded data from different data gathering methods. Contradictory data was sought to revise the hypotheses. Reliability checks for coding were conducted by a research team.

FINDINGS

The knowledge base of instructional representations included knowledge of subject matter, students, curriculum, context, and alternative representations. Within each category there were many subcategories where selected examples were given.

Knowledge of subject matter

Subject matter was the raw material for representations. The teachers' subject matter knowledge included biology terms, structure of concepts, classification, science-technology-society issues, real life stories of biologists, other related subject matters, and scientific methods.

Biology terms. The biology terms included names of organisms(e.g., frog, amphibian), terms of biological structure(e.g., cell membrane, nuclear), and biological events and behaviour(e.g., metabolism, reproductive behaviour). Most of these terms were experiential terms that could be observed or manipulated by their students. Some were more abstract for instance, probability and gene. Biological terms were basic tools for communicating between biologists. Some of these terms(e.g., classification, evolution, consumer, producer) were also used in everyday life or other disciplines but had different definitions and meanings. Their students were easily confused when learning these terms.

Structures of concepts. Structures of concepts were higher level knowledge in biology. Principles and rules(e.g., Mendel's principle of genetics, Darwin's natural selection) were examples of the structure of concepts. The teachers also used other connections to organize different concepts. There were comparison(e.g., comparison between mitosis and meiosis), anthropomorphism/teleology(e.g., the purpose of meiosis is to generate gametes), history/development (e.g., the life cycle of the frog), structures and function (e.g., the function of beautiful petals of a flower is attracting insects to act as pollenators), and interaction between plants, animals, and environment(e.g., food chain, ecosystem). These structures also helped their students to connect learned concepts.

Classification. Taxonomic classification was an important topic in biology. The teachers presented only one well-defined schema and provided typical examples of each category. They never

mentioned the difficulty of classification on some species that had characteristics of different categories. The reason for the teachers to do this was to simplify the content and because the concept did not appear in the textbook. The teachers also asked their students to classify according to teacher-set criteria. For example, Betty asked her students to classify animals into two groups by structures of wings. According to Betty, this classification helped students to organize the complex facts into a system.

Science-technology-society issues. The teachers mentioned science-technology-society issues in different topics. Moral issues of genetic technology and the environment pollution of nuclear energy were commonly used in the teachers' lessons. They tried to show their students that knowledge of biology was not independent of humans' living. Amy said, "Through the discussion of the application of genetic technology, students had a chance to think over the relationship between human being and science."

Stories of biologists. Examples the teachers included in their classes were the development of Charles Darwin's evolutionism, the experiment design of Louis Pasteur's finding of bacteria, and the story of the "Father of Genetics", Gregor Mendel. They believed that these scientists' stories could provide students with the social and cultural context, the development of science concepts, and the humanity perspectives of science. After introducing the story of Darwin, Debra said, "The story could tell students that the evolutionism was not discovered suddenly. It took a long time to develop and it interacted with the existing social value." Their students always showed high interest in personal stories of famous scientists.

Other subject matters. The genetic probability used knowledge in mathematics. Energy transfer in the organism was a physics problem. The teachers also mentioned many chemical terms and chemical reactions for instance, in the photosynthesis topic.

Scientific methods. Observation, manipulation, and integration were the major process skills the teachers emphasized in classes. Most of the laboratory classes occurred in a manner that followed the teachers' instructions and tested the preexisting hypothesis. Logical reasoning including induction and deduction was presented both in laboratory classes and teacher interpretations.

The strong knowledge of subject matter helped the teachers to identify the main objectives of biology instruction, and made

them be able to explain the fact, concepts, structures and methods of biology more clearly. In addition, the knowledge of other subject matters helped the teachers to understand biology more deeply and to translate the content in a way that was more comprehensible to their students.

Knowledge of Students

The teachers' knowledge of how students learn led them to select different teaching strategies. This kind of knowledge included motivation, students' knowledge, indexes of students' understandings, learning difficulties, common misconceptions, and individual difference.

Motivation. The teachers used different motivation forms to encourage students to participate in learning. These practices were based on the knowledge that motivation was the prerequisite of effective learning. Motivation took the forms of setting up a pleasant climate, giving praise to the students, relating the content to students' life experience, and manipulating the proper degree of difficulty for learning. They had different favoured strategies. Giving praise and relating science to life experience were apparent in Amy's and Debra's classes. Betty and Christine favoured manipulating questions to encourage their students to participate in learning.

The students provided their perception of the classroom climate by interviews. The general impression was that biology was one of the favourite classes in the seventh grade and that the teacher made learning interesting and easy. A student of Amy perceived that their teacher was kind and willing to support them. A student said that Betty was enthusiastic in providing opportunities to facilitate learning. One of Christine's students felt that their teacher was just like a friend always listening patiently to them. A student in Debra's class said, "He liked to ask questions, because he felt pride when asking questions and this helped every student to learn during the interaction."

Students' knowledge. The teachers were concerned about how much knowledge base students had in science knowledge, reasoning skill and life experience. When this was ascertained, they could provide opportunities for students to relate the new content to the old one. The teachers reviewed related topics and experimental process skills learned in earlier lessons or in

elementary school. They provided examples that were familiar to students to facilitate learning abstract concepts. The teachers also indicated that some learning difficulties came from students' insufficient formal reasoning ability. Learning difficulty in genetics was a case in point.

Indexes of students' understandings. The four teachers all emphasized that their teaching was based on developing understanding. They used monitoring skills such as test, informal quiz, encouraging students to ask questions, calling students up to explain or clarify their answers, and eye contact to diagnose learning difficulties.

In whole class activities the teachers showed different strategies to monitor students' understanding. Eye contact seemed an effective and economic way to detect when something was wrong between themselves and their students. They could easily tell from students' behaviour, gestures, and expressions on their face if lessons were not clear. Then they used other strategies to diagnose students' learning. Amy always used an oral test strategy. Betty gave an informal quiz that took about 5-10 min at the end of the period. Christine interviewed students when class was over, and she also used an informal quiz to identify students' difficulties. Debra frequently encouraged her students to ask questions. Sometimes she spent half an hour in discussing student-initiated questions in a 50-min lesson.

During laboratory activities the teachers all moved around the groups, reinforced positive aspects of technique, and identified instances of incorrect technique.

They all regarded these interactions as a useful way to gain feedback from their students and to give clarification and encouragement to students regarding their understanding.

Learning difficulties. The teachers were aware of common difficulties while learning biology. The common characteristics of learning difficult topics were complexity, having too many terms, being abstract, and not being observable with the naked eye. Most of these topics were within genetics, cell biology, and evolution. Therefore they used illustration, example, drill and practice, and discussion to help students overcome difficulties. Each teacher had their own favourite strategies in this situation. Amy favoured an example. Betty usually selected illustration. Christine related science to general knowledge. Explanation was the principal form of Debra.

Common misconceptions. The teachers knew the usual misconceptions that students tended to have. Thus, they could diagnose and remedy these misconceptions effectively. They also indicated that the possible sources of misconceptions were teachers' representations, common terms and sense, and students' overinference from examples or facts. They carefully reflected on their representations, pointed out the difference between science concepts and common sense, and provided contradictory examples to help students truly understand.

Individual difference. The knowledge of individual difference enabled the teachers to select different representations to help students learn. The practices of these four teachers in this facet had similar features. In whole class activity all their students were encouraged to be involved in class discussion. Each teacher sought answers from the weaker students though they were not volunteers. In group activity when some groups had completed their assignment in advance of others, they were given extension work. Meanwhile, the teachers gave help to the weaker groups. All four teachers encouraged peer cooperation in group activity, by asking more able students to assist others.

The teachers suggested off-curricular activities for students who had special interests. A simple experiment was the activity these teachers suggested most often. Betty also encouraged students to watch related TV programs. Debra always introduced reference books for the challenge of discovery by reading. Teachers gave feedback to students for these kinds of behaviour. There were limited cognitive-level help and no content modification for the low-achievement students. The teachers focused on behaviour correction for this group.

Curriculum knowledge

Biology curriculum. In four classrooms, teaching content was defined by the textbook. The teachers never deleted any concepts, activities, and questions. The teachers had limited opportunities to change the existing pattern. However, they added proper content, ordered the sequence, linked the concepts of different topics and lessons, and selected or generated the proper teaching media or activities to guide students to learn the concepts and to compensate the insufficiency of the textbook.

Space. The space of lessons followed the syllabus that was set up by all biology teachers in their particular schools. Lessons were always just on time or more likely late according to the teacher's preexisting outline. If the class was late other off-class time would be arranged to teach the remaining content.

Lesson structure. The teachers structured their 50-min lesson in a manner that began with review, followed by introduction, extensive interpretation, and ended with conclusion. Debra always forecasted the topic of the next lesson.

Knowledge of teaching media

The textbook. The teachers were familiar with the intended objectives, content, and structure of the textbook. They pointed out the improprieties and analyzed the learning difficulties.

Remedy materials. For remedying the insufficient and improprieties, the teachers designed or presented different materials. These included activities, pictures, films, papers, and specimens.

Effectiveness of teaching media. The teachers knew the advantage and limitations of teaching media on students' learning. The teachers indicated that the teaching medium provided students with rich information and concrete experience. For these reasons their students had more opportunities to relate the facts and concepts for meaningful learning. Betty said, "Pictures and films could provide students with more information than explanations. The visual learning was more concrete than the audio learning."

These media also had limitations. The teachers agreed that some students were confused by the extra complex facts and that others were disattracted by the animated appearance and did not pay attention to key points. Amy said, "Remedy materials sometimes did not help students to learn because of too much to handle in the same time." Debra said, "Some students were only interested in manipulating the materials and did not learn concepts."

Contextual knowledge

Expectation. Expectations held by society, the school, parents, and students influenced the teachers' roles. The expectation of high achievement in examinations influenced their instructional emphasis, test frequency and test content. School

administrators, colleagues, parents, and students thought that clear, orderly, and quiet classroom environment were prerequisites of effective learning. Their ideas of prerequisites of effective learning made Betty suffer under much pressure when she implemented new representations that opened more freedom for learning activity and put more responsibility on students for their own learning. She always needed to explain that the new activities could help them learn other important things and persuade her students to cooperate with her. Students' images of a good biology teacher as someone who knew everything about the subject matter made Debra act as a knowledgeable scholar who knew all the answers or how to find the answers of student raised questions.

Resource. The hardware and software in and out of the classroom had an important impact on the way that all the teachers used materials and media. They knew where and who would provide resources for teaching, and they could learn new methods and knowledge for improving their instruction when they felt the need. University libraries, science museums, the educational data center, botanical garden, zoo, and national garden were the places where they or their students usually visited. All four teachers built good relationships with university professors, consultants of the teacher center, and colleagues who would provide assistance and suggest alternatives when asking for help in solving teaching problems.

The Entrance Examination for further study. After finishing study in junior high school, most students would take an entrance exam used to select students for high school education. Biology was one of the important subjects included in the entrance exam. Almost all the parents expected their children would have a chance to go to high school for further education. Helping students pass the entrance exam became the dominant goal of secondary education. The entrance exam made all four teachers cover the entire textbook, because the textbook was the major reference used for the exam. It restricted the teachers' role to being more like a textbook interpreter than a curriculum designer. The teachers also emphasized the content that had previously appeared on entrance exams. Context knowledge made the teachers adjust their teaching behaviour to their practice environment.

Knowledge of alternative representations

The teachers' knowledge of alternative representations included forms of representations, models of using representations, and contexts of using different representations. The extensive knowledge of alternative representations made the teachers form their teaching models and show teaching flexibility.

Forms of representations. Several different forms of representations were demonstrated by the teachers. Depending on the major actor of representation, the forms of representation could be classified into three groups: teacher-centered, teacher-student-centered and student-centered forms of representations. In the teacher-centered form of representation the teacher was the major actor. The teachers would communicate knowledge by language and words, using analogy, metaphor, cause and effect interpretation, example, and definition. They also would communicate knowledge by language and words accompanied with pictures and specimens. There were illustrations and demonstrations. In the teacher-student-centered form teacher and students had frequent interaction and communication. Accordingly by characteristics of questions, open or closed, and students' reactions, this form of representation could be grouped into two subcategories: question & answer guide and discussion. In the student-centered form of representation, students were the major actors. Manipulation, simulation game and homework were the components of this form. The predominant forms of representation were question & answer guide, discussion, cause and effect interpretation, manipulation, illustration, and demonstration.

Models of using representations. The teachers usually began with a teacher-centered form to introduce a new concept, followed by teacher-student-centered or student-centered form for helping students to thoroughly understand. If students were familiar with concepts, for instance, classification and food webs, to begin they would choose the form where students could actively participate, as in a discussion or a simulation game.

In laboratory classes the teachers first interpreted the goals and procedures of experiments. Student manipulations occupied the middle period of the classes. Then, the classes ended with discussions or question & answer guides.

Contexts of using different representations. The teachers used different representations in different teaching context. These findings were grouped by forms of representations.

An **analogy** or a **metaphor** was presented when the teachers used a familiar concept or subject for students to understand an unfamiliar and abstract concept. They always appeared in a one or two sentence style. For instance, "A pollen tube can transfer sperms just like a water tube can transfer water. They both have the function of transportation."

A **cause and effect explanation** was used when the teachers wanted to explain the logical relationship of two phenomena when a teacher or student raised a question.

An **example** was given when the teachers wanted to provide concrete or specific information about a rule, principle or abstract concept.

A **definition** was usually presented to summarize the meaning of forward representations. This also appeared as an advanced organizer.

Illustrations and **exhibitions** combining the audio/visual learning were presented when the teachers taught abstract concepts, complex procedures, and the morphosis and structure of biology.

A **demonstration** was usually used to show the experimental process skill.

A **question & answer guide** was used when the teachers wanted to divide a complex difficult question into a series of simple easy questions. It was a small step strategy by which teaches could easily guide and monitor each step of student learning.

When students had enough prerequisite knowledge, the teachers considered the use of **discussion** inviting students to participate in a learning activity for applying the concept to solving the new problem.

Student manipulations were the major activities of laboratory classes.

Simulation games would be used when the teachers presented concepts that had complex interaction and could not be observed for a short time. Meanwhile the teacher wanted their students to actively participate in the learning process.

When the teachers wanted to extend learning time to an out-of-class period, they assigned **homework**. Homework was always an

independent study, such as, completing an experiment report and watching a related TV program.

CONCLUSION

The experienced biology teachers' instructional representations were based on their strong knowledge. The categories of knowledge base including knowledge of subject matter, students, curriculum, context, and alternative representations exist simultaneously as a knowledge system. They are able to use knowledge from different categories in all aspects of presenting representations.

They appeared to have the characteristics of expert teachers. It appeared that they had developed the complex schema for teaching as Leinhardt and Greeno(1986)described. Their thoughts seemed to encompass three categories: planning, interactive thoughts and decisions, and theories and beliefs(Clark & Peterson(1986). All of them also seemed to have the mental scaffolding of experienced teachers(Peterson & Comeaux, 1987).

These teachers' knowledge developed through the processes of continuous learning and reflection. Similar to the study by Wallace and Louden(1992), the teachers' knowledge developed through a gradually expanding process rather than by sudden leaps of insight. Their repertoire constantly expanded by "thousands of hours of instruction and tens of thousands of interactions with students", as described in Berliner(1987).

They had rich resources for learning to teach. Personal learning, teaching experience, the textbook, other teachers, volunteer worker training, in-service training, university professors, library services, and students' response were all probable sources for the teachers acquiring a knowledge base.

Subject matter was the content of representations. The teachers' subject matter knowledge included the substantive and synthetic structure of a discipline (Schwab, 1978). Their understanding of subject matter far exceeded the content of representations. All four teachers' knowledge of subject matter continually developed, especially in the areas of science-technology-society issues, content related to everyday life of students, stories of scientists and concrete knowledge that could help students to construct their new knowledge. This result was similar to other studies(Hauslein, Good & Cummins, 1992; Lederman, Gess-Newsome & Lantz, 1994)that described teachers'

reorganization and reconstruction of their complex, huge, and yet loosely organized subject matter for the need of teaching.

Knowledge of how students learned made these teachers consider what kind of learning opportunity needed to be provided. All had extensive knowledge of how their students learned. Most of this knowledge came directly from their own teaching experience. Expansive knowledge of curriculum and teaching media enabled the teachers to arrange proper learning activities.

Knowledge of alternative representations included not only various forms of representations, but also the correct time to use them and the proper reasons for using them. These all were important components of the experienced teachers' knowledge. These findings could further articulate the concept of pedagogical content knowledge. The extensiveness of knowledge of alternative representations made the teachers form their own teaching routines, and it also made them show teaching flexibility in their individual circumstances.

The results also demonstrated that context knowledge played an important role for the teachers to represent knowledge similar to the suggestion of Cochran et al. (1993). The teachers learned how to teach over many years. Their knowledge construction involved not only self-organization, but also a social process. All four teachers were socialized into practices of school science teaching and the ways of knowing. Social culture provided conditions for these teachers to construct personal meanings. Sometimes teaching context restricted the teachers' instructional representations, othertimes it worked as facilitators or supporters of the teachers ' actions.

The results suggest that it be important to provide science teachers with extensive knowledge base. Science teacher educators should try to provide teachers with knowledge of subject matter, students, curriculum, context, and alternative representations. Particularly, it is necessary to help teachers integrate the different categories of knowledge for teaching. These are essential subject matters for the teacher education curriculum.

These teachers have a wealth of ideas about instructional representations. The knowledge that expert teachers have should be shared with all those learning to teach. Further studies should be conducted with different teachers, research methods and subject matters to enrich the knowledge base of instructional representations.

REFERENCES

Berliner, D. C. (1987). Ways of thinking about students and classrooms by more and less experienced teachers. In J. Calderhead(Ed.), Exploring teachers' thinking. London: Holt, Rinehart & Winston.

Bruner, J. S. (1966). Toward a theory of instruction. New York: W. W. Norton.

Carlsen, W. S. (1990). Subject-matter knowledge and science teaching: A pragmatic perspective. In J. E. Brophy(Ed.), Advances in research on teaching: Vol. 2. Teacher's subject matter knowledge and classroom instruction. Greenwich, CT: JAI Press.

Carter, K. (1990). Teachers' knowledge and learning to teach. In W.R. Houston(Ed.), Handbook of research on teaching education. New York: Macmillan.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. Wittrock (Ed.), Handbook of research on teaching(3rd ed.). New York: Macmillan.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowledge: An integrative model for teacher preparation. Journal of Teacher Education, 44(4), 263-272.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock (Ed.), Handbook of research on teaching(3rd ed.). New York: Macmillan.

Geddis, A. N., Onslow, B., Beynon, C., & Oesch, J. (1993). Transforming content knowledge: Learning to teach about isotopes. Science Education, 77(6), 575-591.

Gess-Newsome, J., & Lederman, N. G. (1995). Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. Journal of Research in Science Teaching, 32(3),301-325.

Grossman, P. L. (1989). A study in contrast: Sources of pedagogical content knowledge for secondary English. Journal of Teacher Education, 40(5), 24-31.

Hashweh, M. Z. (1987). Effect of subject matter knowledge in the teaching of biology and physics. Teaching and Teacher Education, 3(2), 109-120.

Hauslein, P. L., Good, R. G., & Cummins, C. L. (1992). Biology content cognitive structure: From science student to science teacher. Journal of Research in Science Teaching,

29(9), 939-964.

Lederman, N. G., Gess-Newsome, J., & Lantz, M. S. (1994). The nature and development of preservice science teachers' conceptions of subject matter and pedagogy. Journal of Research in Science Teaching, 31(2), 129-146.

Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. Journal of Educational Psychology, 78(2), 75-96.

Marks. R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. Journal of Teacher Education, 41(3), 3-12.

McDiarmid, G. W., Ball, D. L., & Anderson, C. W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In M. C. Reynolds (Ed.), Knowledge base for the beginning teacher. Oxford: Pergamon Press.

News & Views (1989, Sep/Oct). Characteristics of an outstanding biology teacher. 7-8.

Penick, J. E. (1984). Exemplary science programs in the United States. Paper presented at the First Asia-Pacific Conference on Science Education. Taiwan.

Peterson, P. L., & Comeaux, M. A. (1987). Teachers' schemata for classroom events: The mental scaffolding of teachers' thinking during classroom instruction. Teaching and Teacher Education, 3, 319-331.

Post, T. R., & Cramer, K. A. (1989). Knowledge, representation, and quantitative thinking. In M. C. Reynolds (Ed.), Knowledge base for the beginning teacher. Oxford: Pergamon.

Sanders, L. R., Borko, H., & Lockard, J. D. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. Journal of Research in Science Teaching, 30(7), 725-736.

Schwab, J. J. (1978). Education and the structure of disciplines. In I. Westbury & N. Wilkof (Eds.), Science, curriculum, and liberal education: Selected essays. Chicago: University of Chicago Press.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundation of the new reform. Harvard Educational Review, 57(1),1-22.

Wallace, J., & Louden, W. (1992). Science teaching and teachers' knowledge: Prospects for reform of elementary

BEST COPY AVAILABLE

classrooms. Science Education, 76(5), 507-521.
Yager, R. E. (1986). Searching for excellence. Journal of Research in Science Teaching, 23(3), 209-217.